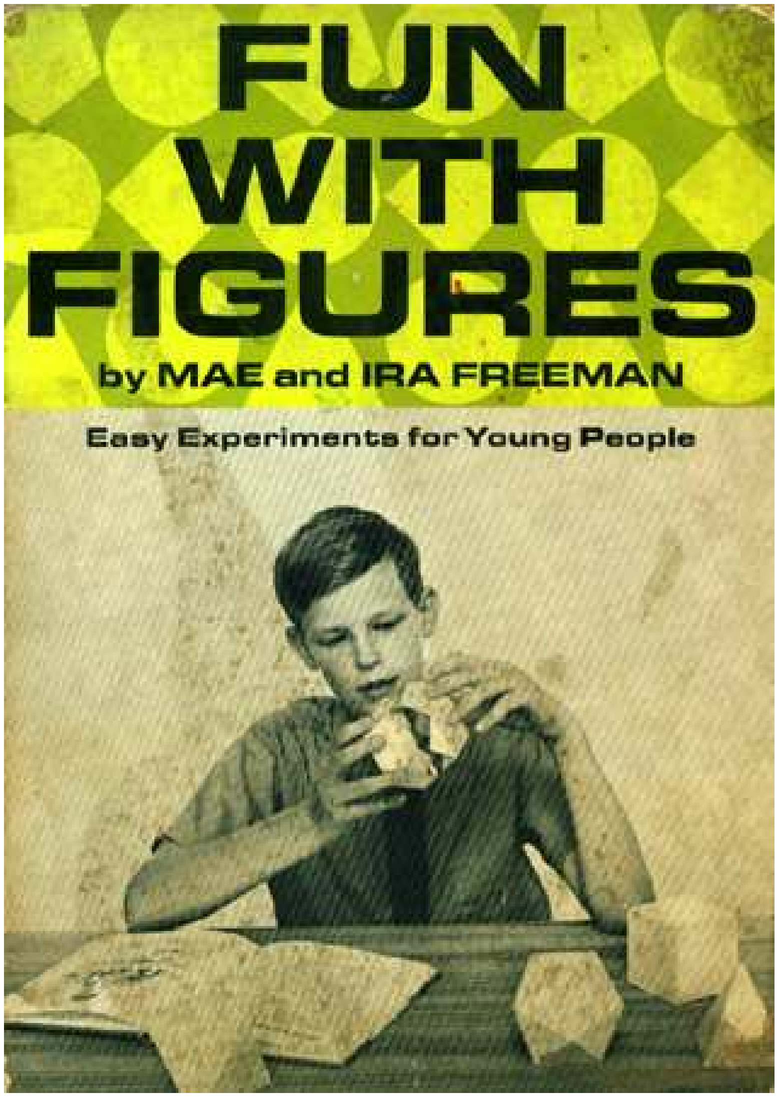


INTRODUCTION

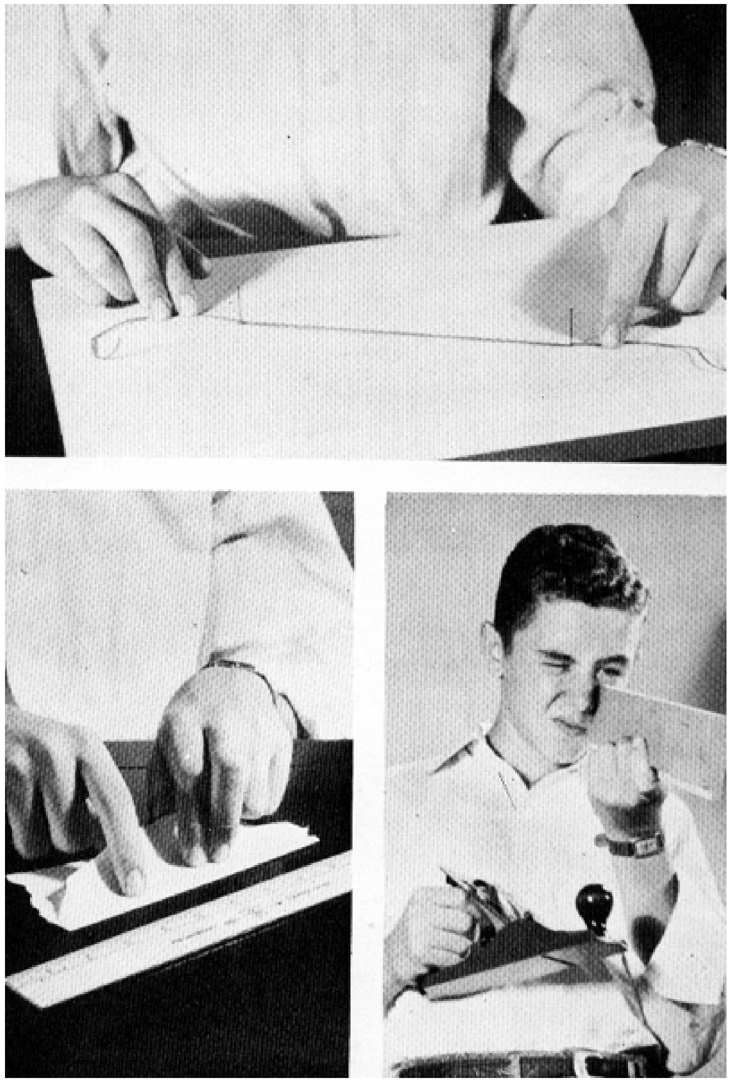
The "Figures" referred to in the title of this book are triangles, squares, circles and other shapes drawn and used in *geometry.* This science was used in Egypt at least five thousand years ago to measure land flooded by the River Nile, and the name geometry comes from Greek words meaning "earth-measuring."

Today, many useful and beautiful articles are designed with the help of geometry. Artists and craftsmen often use geometric figures and patterns. Engineers rely on this branch of mathematics constantly when they plan bridges, tunnels, machines and buildings.

In the following pages you will become acquainted with some of the facts and uses of geometry by making drawings and cut-outs and by other interesting activities. Besides being fun to do, the projects will give you a real understanding of one of the most important branches of mathematics.

The boy in the pictures is Robert Delsasso. He is 15 years old and attends high school in Princeton, New Jersey.

STRAIGHT LINES



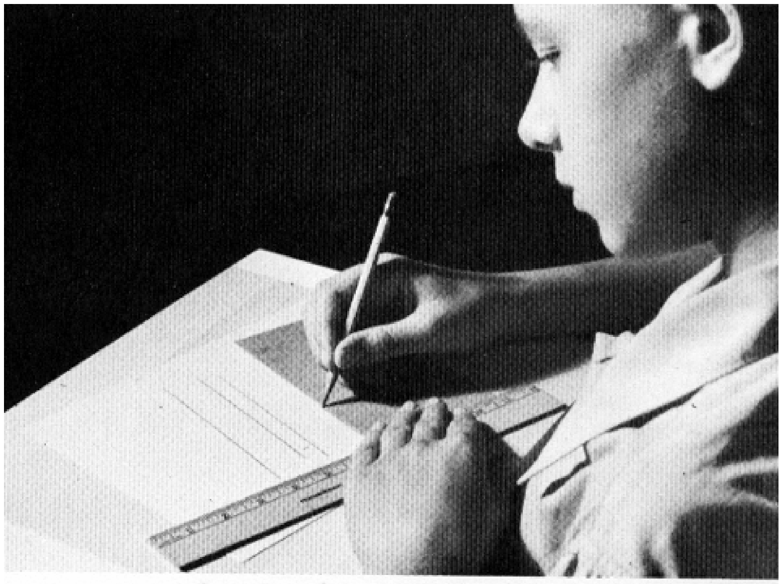
If you were asked to make a careful drawing of a house or table, you would probably use a ruler to draw the straight lines. But suppose you had no ruler—how would you draw an accurate straight line? This is really an important question because straight lines are used so much in the things around us. The edges of your desk, of the room or of the sidewalk are straight, and straight lines mark off the tennis court and baseball diamond.

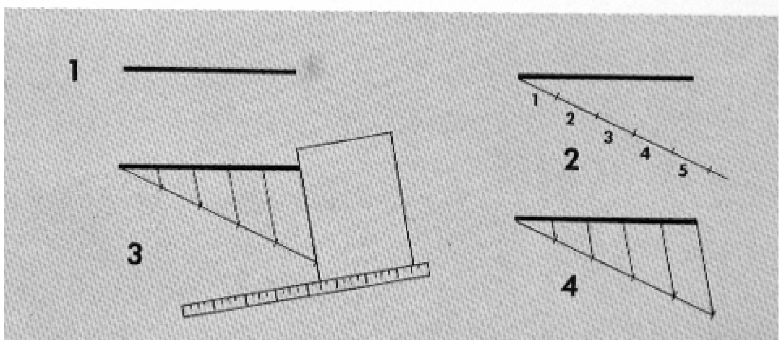
Drawing a straight line without the help of a ruler is easy, once you know what such a line really is. A straight line is simply the shortest path between one point and another! That is, if you want to get from one place to another by the shortest possible route, you follow a straight path rather than any other. One of the simplest ways to get a straight line is to stretch a thread between two points, as in the photograph. As long as the thread is pulled tight, it is certain to be straight.

Another way to make a straight line is simply to fold a piece of paper. No matter what the shape of the paper itself, the fold will be perfectly straight when placed flat on the table, as the next picture shows.

A good way to see if a line is straight is to sight along it. Robert is doing this in the last picture, in order to see if the edge of the board has been planed straight.

LINES THAT NEVER MEET



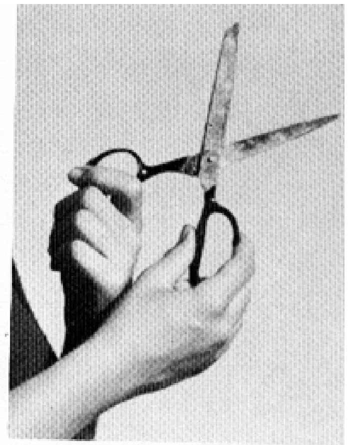


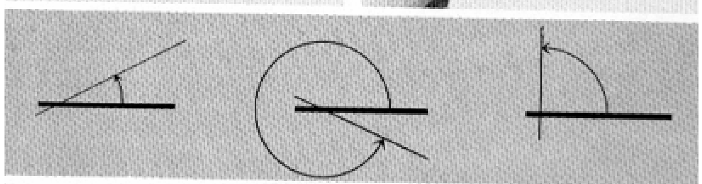
Two straight lines that never cross each other, such as the rails of a railroad track, are called *parallel* lines. No matter how far you follow them, they always remain the same distance from each other, getting no closer together nor any farther apart. Other examples of parallel lines are the two opposite edges of a door or of a book.

Architects and engineers have a simple way of drawing parallel lines. Do the same thing by using a ruler and a piece of cardboard with straight edges. Lay them both on a sheet of paper so that one edge of the card is against the ruler. Hold the ruler and card firmly and draw a line with the edge of the card as a guide. Now, being careful not to move the ruler, slide the card along to another point and draw a second line. The photograph shows how it is done. In this way you can draw any number of lines all parallel to each other.

Knowing how to do this, you can now divide any line into equal parts, even though it is of an odd length and not easily marked off by using the divisions on a ruler. In the first sketch, the heavy line is to be divided into, say, five equal parts. Draw another line downward from one end of the heavy line and on it mark off five equal divisions of any size, as in the second sketch. You can do this with a ruler, using one-inch spaces, half-inch spaces, or any other size you choose. Then place one edge of your card so that it just touches the ends of the two lines (Sketch 3). Through all the division points marked off earlier, draw parallel lines. These will cut the original line into five exactly equal parts, as shown in the final sketch.

ANGLES





When two lines cross, we speak of the <u>*angle*</u> they form. This is simply the measure of the opening between the lines. In the picture of the scissors, for example, the angle between the blades is a measure of how much they were opened. The angle between the hands of a clock is changing all the time.

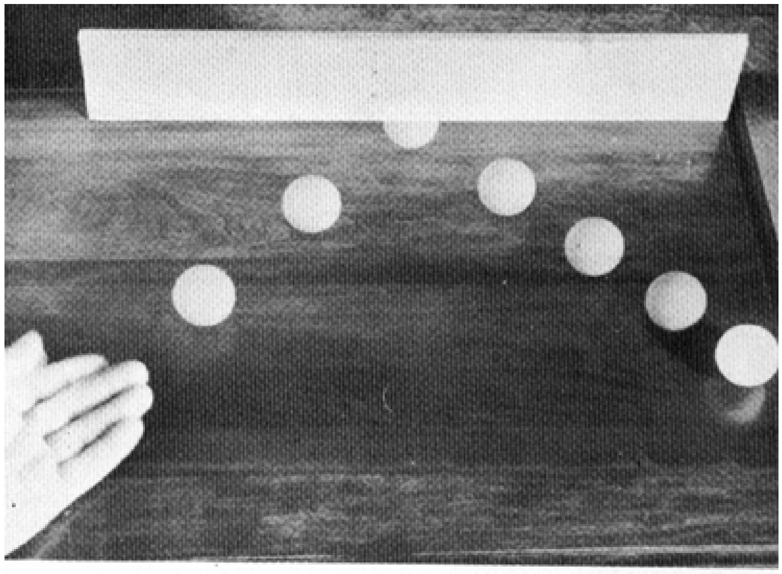
The sketches show two lines—a heavy one which does not move, and a light one which turns as shown by the arrow. One complete turn is called an angle of 360 degrees, and this is written 360°. Half a turn then amounts to one-half of 360°, or 180°, and a quarter turn is an angle of 90". Two lines making an angle of 90° are perpendicular, or are at *right angles* to each other.

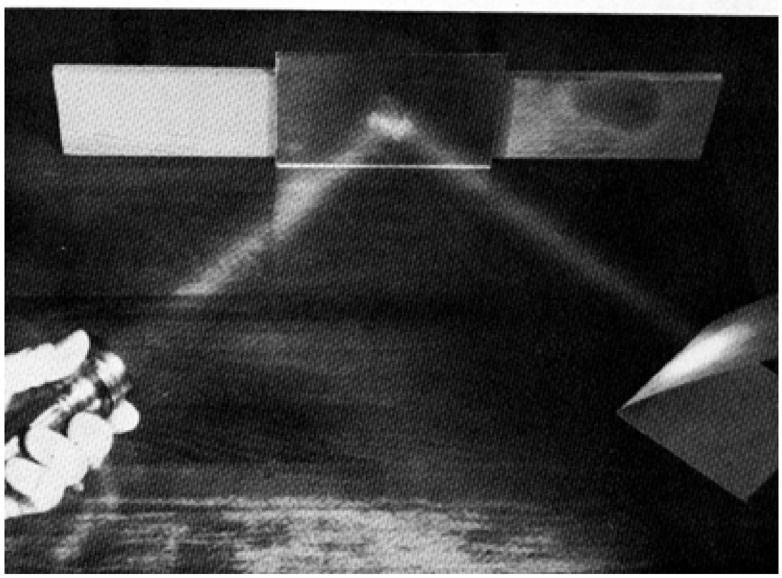
Angles become easy to estimate, once you have had a little practice. Robert is holding the blades in the picture at an angle of about 70°. How large would you judge the angle between the clock hands to be?

A house may be built with a sloping roof for several reasons. Compared with a flat roof, a sloping one has a pleasing appearance, is simpler to build, and allows rain and snow to run off easily. In a place where heavy snows are common, the angle between the two sides of the roof must not be too large, so that the snow may slide off readily.

Look about you and notice the many uses of angles in your surroundings.

REFLECTION ANGLES



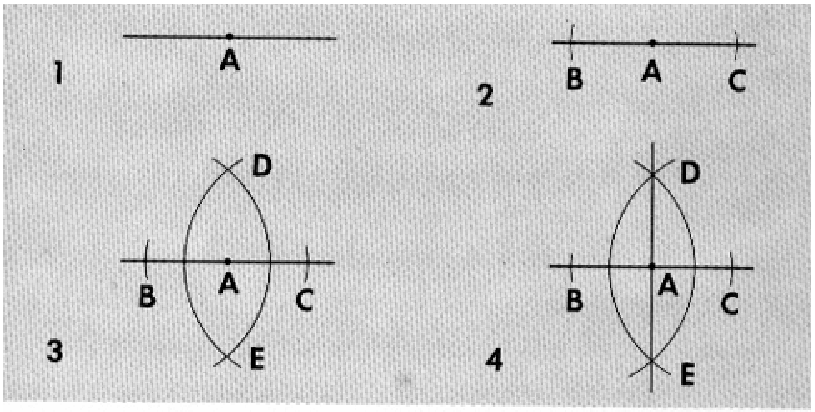


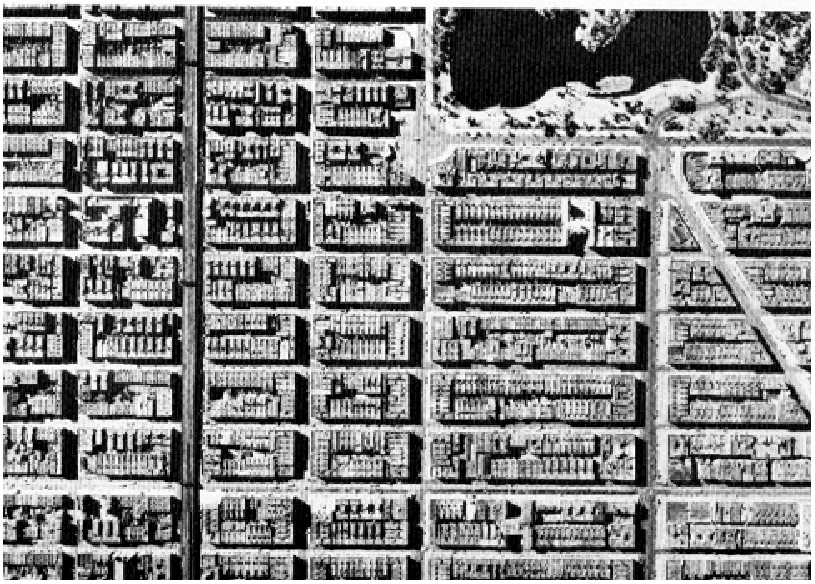
Suppose a ball rolls across the floor, hits the wall and bounces off. The angle at which the ball bounds away again is the same as the angle at which it came up to the wall. This is always true, as you can prove by actual test.

The upper picture was made by taking a series of flash shots of a rolling ball. You can see that the positions of the ball follow through on two straight lines, each making the same angle with the board against which the ball bounced. This fact is useful to know when playing such games as handball, billiards and tennis.

More Important than the bouncing of a ball is the fact that a beam of light acts in this same way. It “bounces off,” or is *reflected* from a mirror at the same angle as it approaches. The lower picture shows the beam from a flashlight reflected from a mirror and then striking a piece of cardboard. If you have a flashlight that can be made to throw a narrow beam, try this experiment. It shows how rays of light are reflected in periscopes, binoculars and other such instruments.

LINES THAT CROSS SQUARELY





Most of the angles we see on familiar things are right angles. You know that two lines that cross at 90° are called perpendicular.

Suppose you wish to draw a line exactly perpendicular to the line in Sketch 1. This is how it can be done. Get an ordinary compass at a school supply or ten cent store. Set the metal point at the place on the line where you want to draw the perpendicular and draw two small parts of a circle, as in Sketch 2.

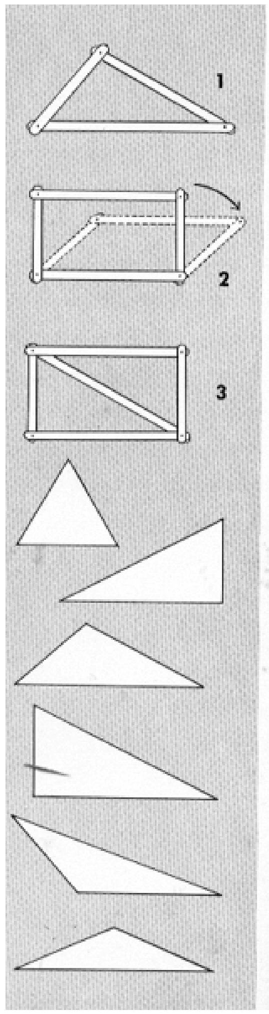
Spread the compass legs a little. Now place the metal point first at B and then at C, drawing two parts of circles that cross each other. Your drawing should now look like Sketch 3.

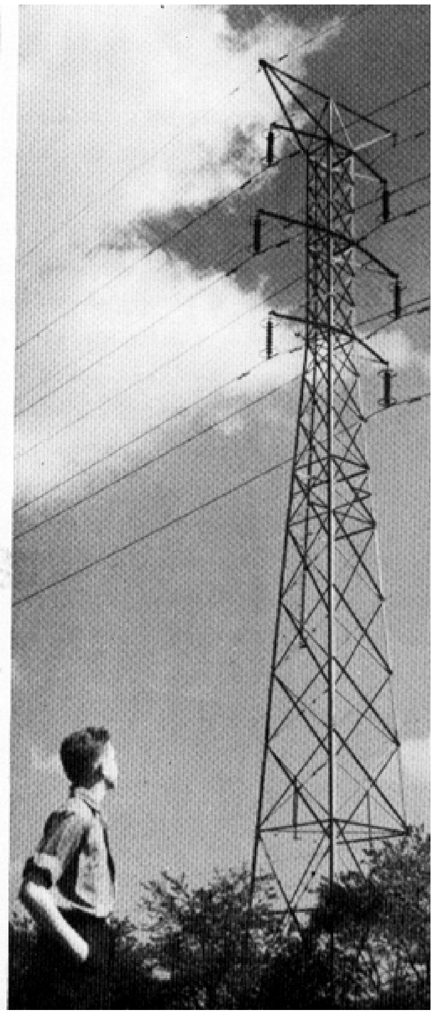
Draw a straight line through the two crossing points D and E. This line also passes through A, and is perpendicular to the heavy line. By repeating the process, you can draw a square. Try it.

Right angles are common simply because they are so convenient. Furniture fits best in a right-angled room. Packing boxes are made in this familiar shape so that they can be stacked without wasting space. Imagine how strange it would be to read a book whose covers were any shape but right-angled.

The photograph, which is an airplane view of part of a large city, shows that right angles play an important part in city planning.

TRIANGLES





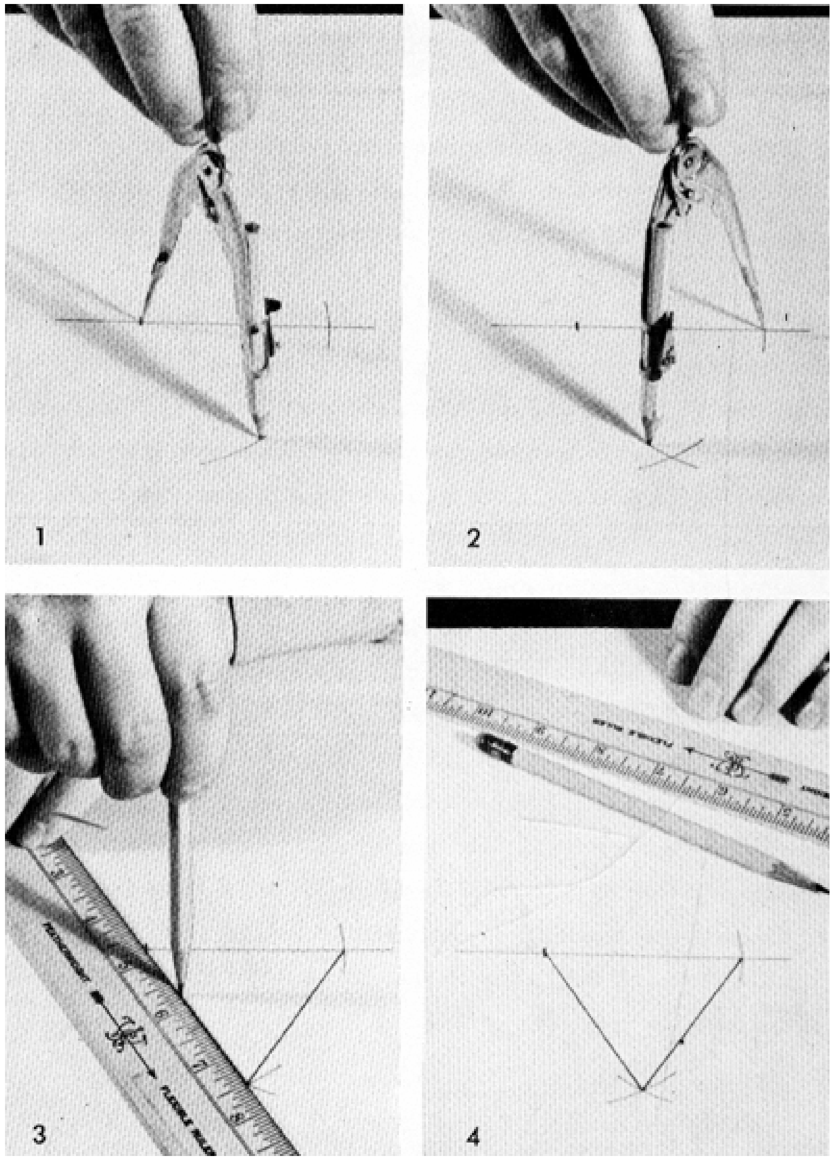
A triangle is a three-sided figure whose sides are straight lines. It is the simplest closed figure that can possibly be drawn with a ruler. You do not have to look far to find many uses for triangles. Structures such as bridges, cranes and radio masts are made up of triangular parts.

Robert has come upon a steel tower for carrying electric power lines and he sees that the whole framework is really a set of connected triangles. The reason for using triangles in place of other forms is that a triangle made of linked-together bars—as in Drawing 1 —holds its shape when pushed or pulled. Nothing short of breaking the bars will make it change its shape. A four-sided figure can be deformed quite easily, as Drawing 2 shows, but if two of its opposite corners are connected by another bar, it will then amount to a pair of triangles which hold their shape. Drawing 3 shows this.

The remaining sketches show various forms of triangles. Find one that has two equal sides, two having right angles, another with all three sides equal, and two with sides all of different lengths.

The study of triangles is a branch of mathematics all by Itself, called trigonometry, and is used in surveying, in navigating ships and planes, and In aiming long-range guns.

EQUAL-SIDED TRIANGLE



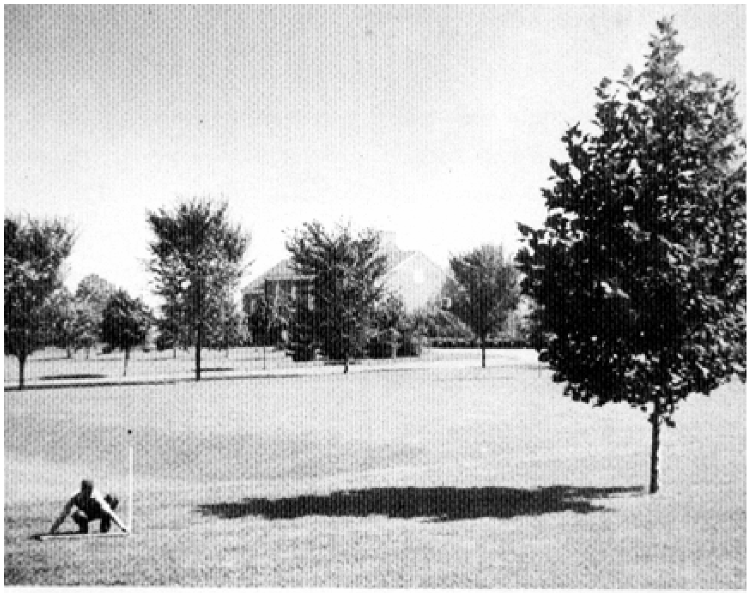
Because of their pleasing shapes, geometric figures are commonly used in designs and decorations. Of the various forms suitable for this purpose, one of the most agreeable is a triangle whose three sides are equal in length. This is called an *equilateral* triangle.

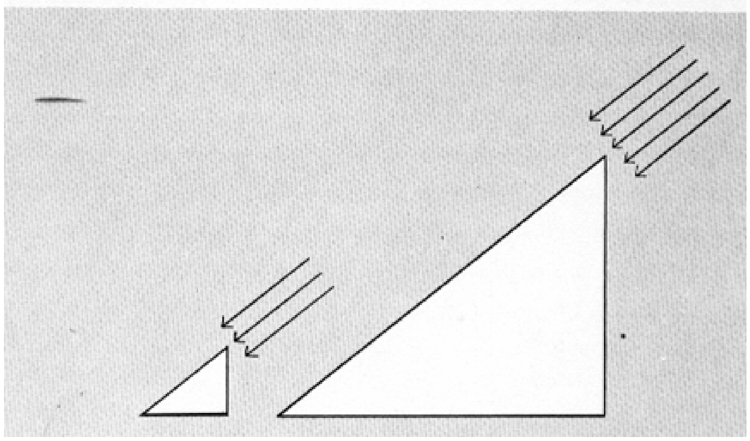
Using ruler and compass, you can draw a perfect equilateral triangle by following the pictured steps. First draw a straight line. Then place the compass point on this line near one end and draw two parts of circles as shown in the first photograph. Without changing the setting of the compass, carefully place the point where the first mark crossed the line and make another mark, like that in Picture 2.

Now join the crossing points with straight lines, as in the third picture, and the result is the equilateral triangle shown in Picture 4.

Looked at from any side, this triangle has the same shape: All of its sides are equal and so are its three angles.

SHADOWS MEASURE HEIGHT





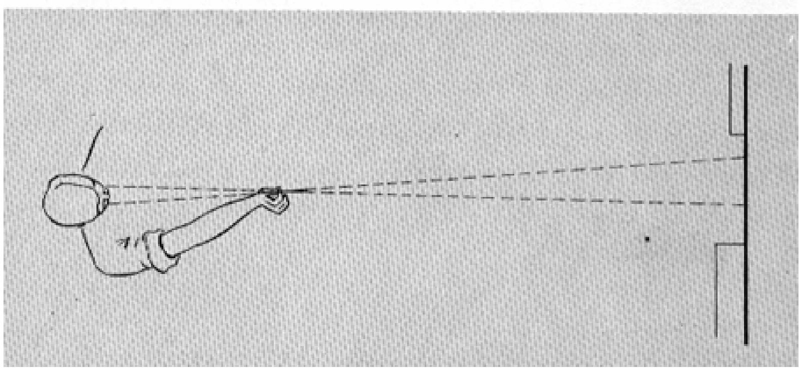
How can the height of a tree be measured without actually climbing to its top? The answer is: Do as a surveyor does—use what you know about triangles and you can figure out how tall the tree is without measuring it directly.

Robert is finding the height of the tree in this way. First he set up nearby a broom handle—any long, straight stick will do. The sun casts a shadow of the tree and also one of the stick. The tree and its shadow form a large triangle, and the stick and its shadow form a smaller one, as shown in the drawing. Since the sun's rays come from the same direction in making both shadows, the two triangles have exactly the same shape and are different only in size.

All that Robert must do is measure the length of the stick and the lengths of the two shadows with a tape measure or ruler. Then the height of the tree is found by multiplying the length of the stick by the length of the tree's shadow and dividing this result by the length of the stick's shadow. For instance, in the photograph, the stick is 4 feet long, the tree's shadow measures 20 feet and the stick's shadow 5 feet. Then the height of the tree is 4 times 20 divided by 5, or 16 feet.

Of course this method of measurement can be used for other objects, too. Use it to find the height of your house, or of the flagpole in the schoolyard.

MEASURING DISTANCES



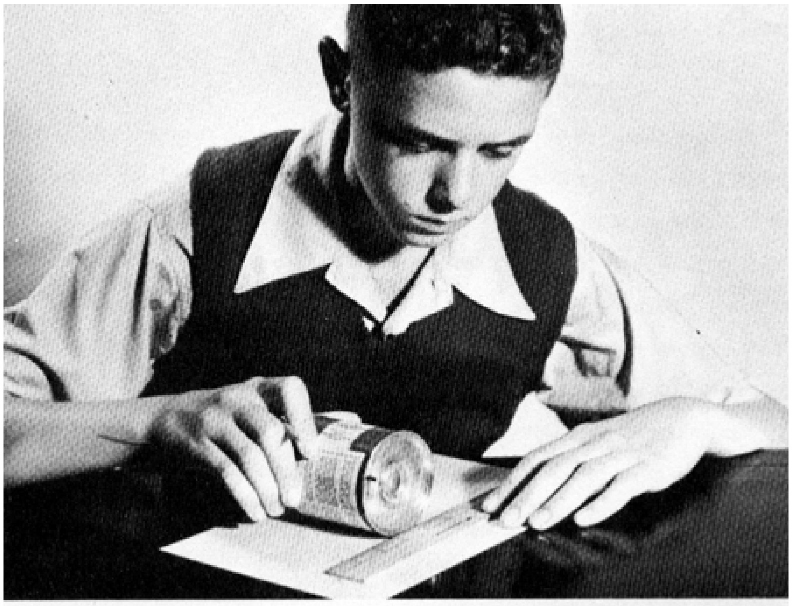
Probably you have seen engineers laying out a new road or the ground plan of a building. For finding distances they use an instrument called a transit, which is similar to a telescope.

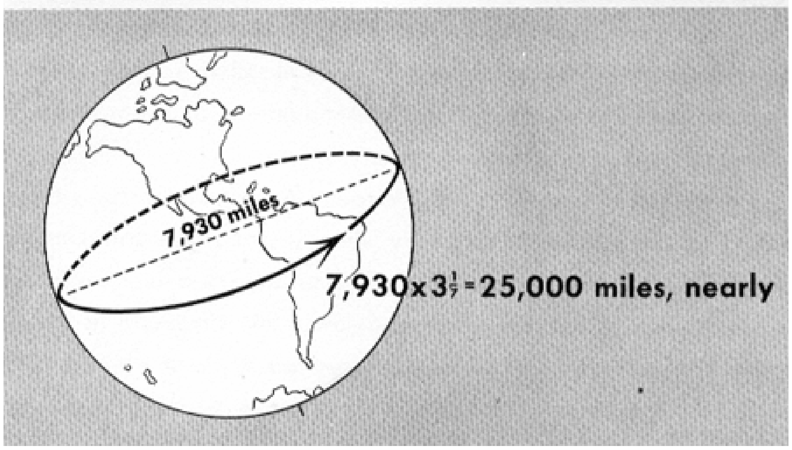
With no instrument but your eyes, you can make rough measurements of distance without using a ruler and without moving from where you stand. Hold your right arm out full length in front of you, with the thumb pointing upward. Close your left eye and notice where the thumb seems to be on a distant house. Then, without moving your arm, close your right eye and sight with the left. The thumb will seem to move to the right across the front of the house. The drawing shows the set-up as seen from above and makes clear what you are doing.

It happens that the length of your outstretched arm is about ten times the distance apart of your two eyes. The distance of the house is then ten times the space your thumb seemed to move. Look at the diagram again to make sure you understand how this simple "range finder" works.

In order to estimate how far the thumb moves, use a familiar object such as a door or window whose width you can judge. For instance, if the distance your thumb seems to jump is about twice the width of a door, you would figure it moves about 5 feet. The distance to the house is then 10 times this, or 50 feet. If, afterward, you should measure the distance directly, you would find your estimate fairly close to the true figure.

CIRCLES



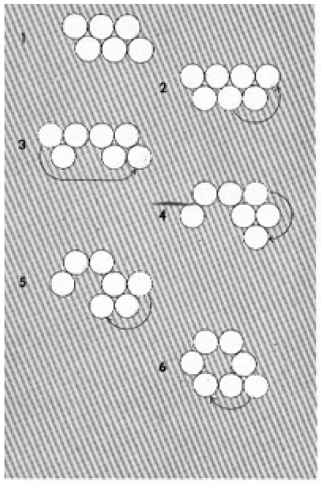


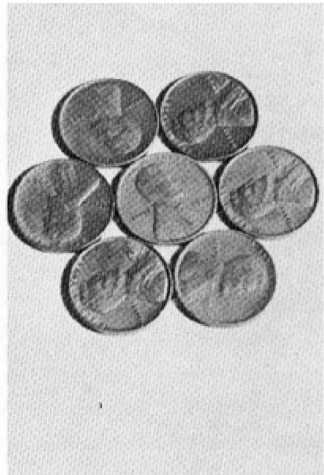
A circle is a curve which is always the same distance from a fixed center. The mathematicians of ancient times called the circle "the perfect curve," and this name seems to be well deserved.

Probably the most remarkable fact about circles is that they are all similar. If the circumference, or distance around any circle is divided by the circle's diameter, or distance across, the result is always the same number. This number is represented in mathematics by the Greek letter pi (pronounced "pie"). It amounts to 3.1416, or about 3-1/7. This means that if you measure the circumference of any circle, it will be 3-1/7 times as long as the diameter of that circle. For instance, the diameter of the earth is about 7, 930 miles. The distance around the equator is then 3-1/7 times 7, 930, or very nearly 25,000 miles.

In the picture, Robert is checking the number pi by measuring the circumference of a circular tin can. First he made a mark on the edge of the circle and placed this end of the can against a ruler. He was careful to have the mark at the bottom and just touching the end of the ruler. Now he is rolling the can along the ruler, making certain that it does not slip. When the mark shows that the can has made one complete turn, he will be able to read its circumference on the ruler. Then he will divide this distance by the measured diameter of the can and the answer will come out very near the value of pi, or about 3.14. Test this yourself in the same way.

MORE ABOUT CIRCLES



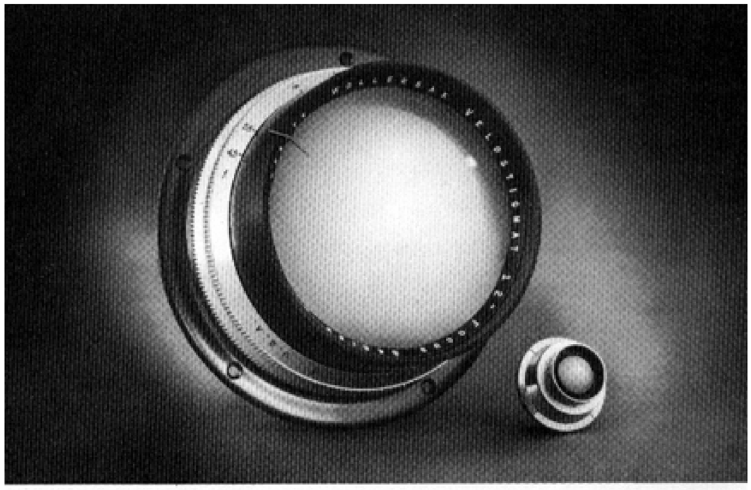


Six equal circles will just fit around the edge of another circle of the same size, with each one touching its two neighbors as well as the one at the center. Prove this curious fact by using seven identical coins. The photograph shows how to do it with pennies. By placing more pennies around the outside of this arrangement you can continue the pattern as far as you please. It would be, for example, the closest way you could pack circular cans into a box,

An interesting question is, how could the six outer coins in the picture be put into their proper places if the middle coin is missing? The sketches show how to do it. Begin by placing the six pennies in two rows of three each, touching one another, as in the first arrangement. Then remove one coin and replace it as shown in Sketch 2. Be sure not to disturb any of the other coins. Continue as directed by the other sketches until you have an exact ring of six coins as shown by Sketch 6. You can test it by carefully dropping another coin In the middle—it will just touch all the others.

Of all the characteristics of the circle, the most wonderful is its use as a wheel. It is often said that the wheel is man's greatest invention, even overshadowing such modern marvels as radio, television and rocket planes. Certainly this is true, because without the wheel and its various forms, such as gears and pulleys, modern industry and transportation would be impossible. And you would be denied such pleasures as roller skating and bicycling. But the inventor of the wheel, probably some citizen of ancient Egypt, must remain forever unknown.

ROUND FIGURES



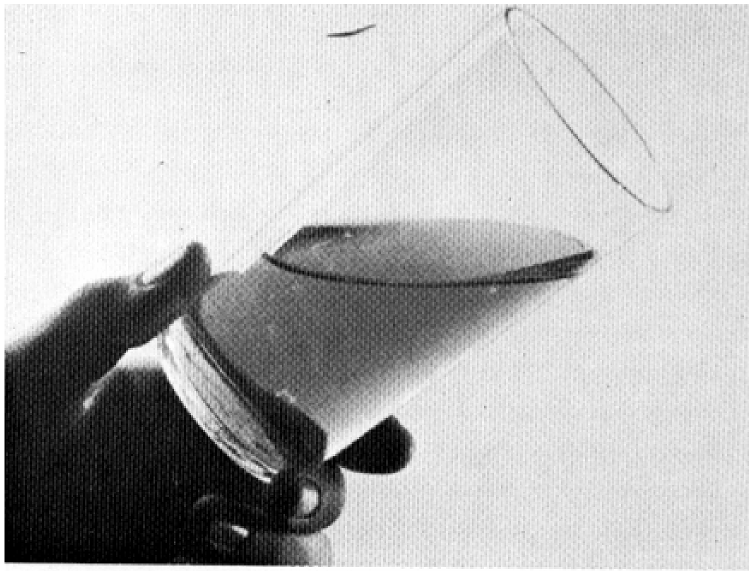
Page 24 shows that the number pi is needed to find the circumference of a circle. Another place where this number is useful is in figuring the area of a circle, or the amount of surface enclosed by it.

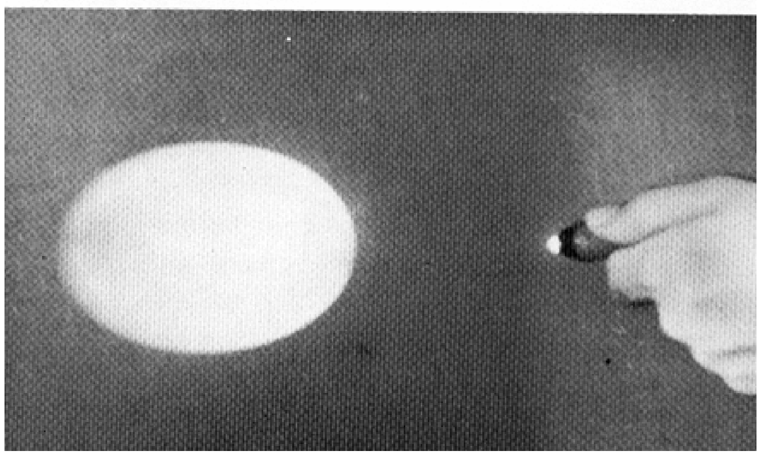
If you were cutting circles of various sizes out of gold foil, a two-inch diameter disk would be worth exactly four times as much as a one-inch disk. The reason is that the area of a circle is figured by dividing pi by 4 and multiplying the result by the diameter and once again by the diameter.

Of the two camera lenses shown in the picture, the larger has a round opening 6 times the diameter of the smaller. This means that the amount of light that the first lens lets into the camera is 6 times 6, or 36 times as much as the second lens, because the amount of light depends on the lens area.

If you want to know the bulk or volume of a ball, you find again that pi always plays a part. The volume is found by dividing pi by 6 and multiplying the result by the diameter *three times over.* The indoor baseball that Robert is holding is about 3 times as big across as the smaller ball. Its bulk is 3 times 3 times 3, or 27 times as great. The sun is about 100 times as large in diameter as the earth. From this, can you figure out how much more bulk there is in the sun than in our planet?

OVALS



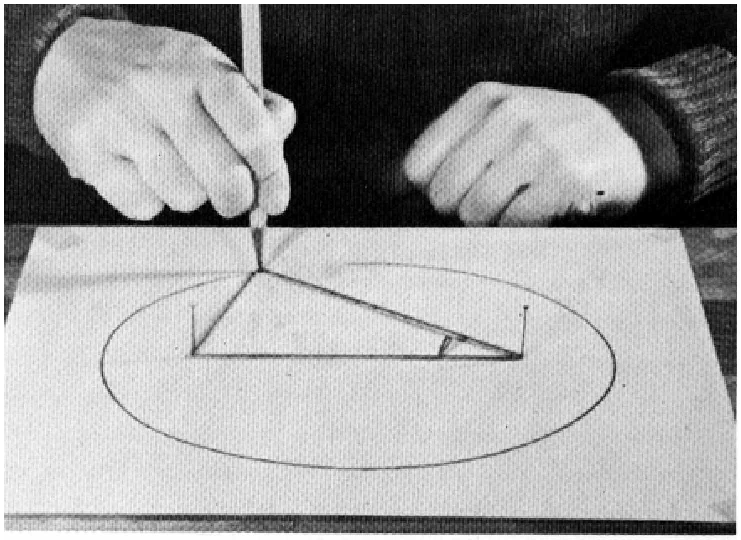


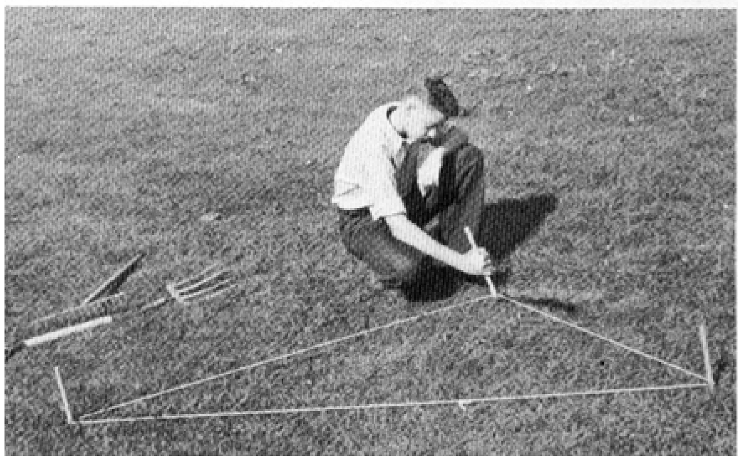
Look at a dinner plate across the table or the wheel of a car some distance up the street. You know that the plate and the wheel are really circles, but when looked at from off to one side they appear to be oval in shape. The oval curve that you see is called an *ellipse,* and It Is a familiar and interesting curve. An ellipse may be nearly round or it may be long and thin. The shape that the wheel or plate seems to have depends on how far to one side you are when looking at it.

The pictures show Robert trying out two ways of making an ellipse. In the first, a glass is about half filled with water and then held in a tilted position. When he now looks straight down at the surface of the water, he sees that its edge is an ellipse. The more the glass is inclined, the thinner the curve becomes. But if the glass is held straight up, the ellipse becomes a perfect circle, showing that a circle is merely a special kind of ellipse which has lost all its oval-ness.

Another good way to make an ellipse is to shine a flashlight on a nearby wall so that the beam of light strikes it at an angle. The patch of light forms a very good ellipse, as you can see from the photograph. Notice here, also, that by shining the light perpendicular to the wall instead of at an angle, you can make the ellipse change to a circle.

HOW TO DRAW AN ELLIPSE



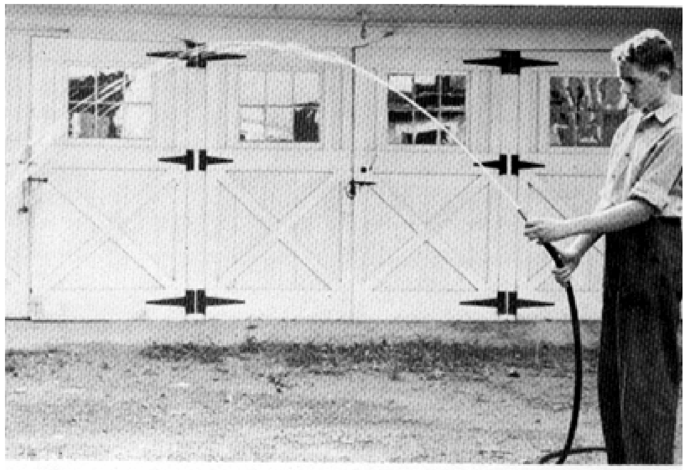


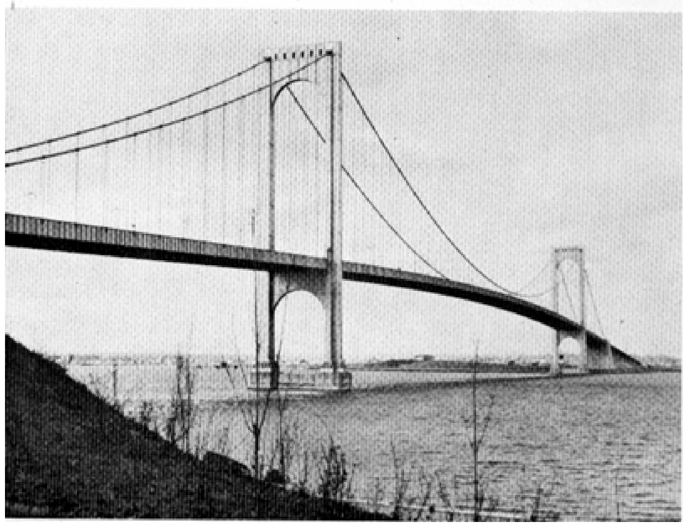
In order to draw a perfect ellipse of any desired shape, fix a sheet of paper to a board and stick two pins or tacks into the board a few inches apart. Tie a piece of thread or thin string into a loop, making the loop a little larger than the space between the pins. Lay the loop over both pins and slip the point of a pencil into it. Then, keeping the loop always stretched tightly, draw completely around as shown in the upper photograph. The closed curve will be a perfect ellipse. To draw other ellipses having either thinner or rounder shapes, change either the distance between the pins or the length of the loop.

Robert decided to use this way of drawing an ellipse in order to lay out an oval flower bed in his front yard. He drove two stakes into the ground, looped a piece of heavy cord over them and used a stick to scratch the outline of the ellipse in the turf. He will then remove the sod inside this curve and plant his flowers.

The ellipse is an important curve in astronomy. Long ago, people believed that the earth stood still and the sun, moon, planets and stars moved around it. Now we know that our earth is only one of the planets and that they all move around the sun, each along a path that has the shape of an ellipse. The moon's path around the earth is an ellipse also. Most of the planet paths are "fat" ellipses, very nearly circles.

THE PARABOLA





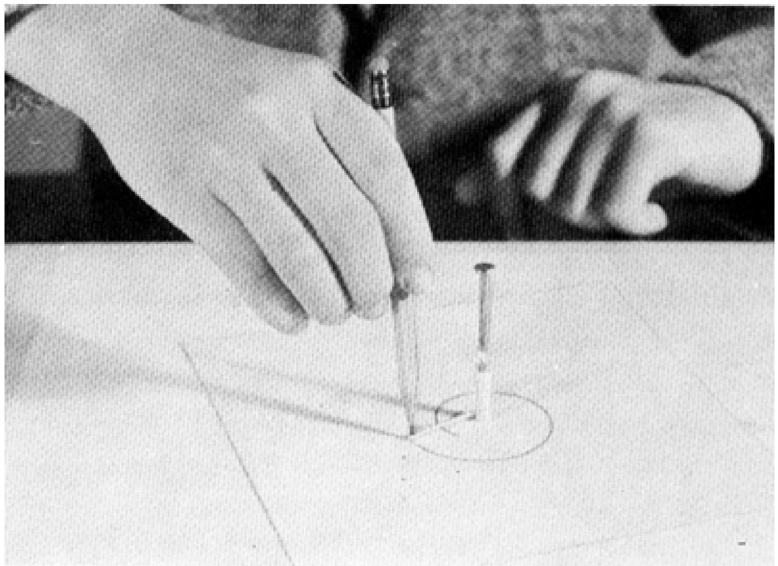
A football sailing through the air and a shell fired from a gun both follow the same kind of curved path. If not for its weight, any object thrown into the air would keep on going in the direction it started out, but the attraction of the earth makes it gradually swerve downward and finally come back to the ground. This path is a curve called a *parabola.*

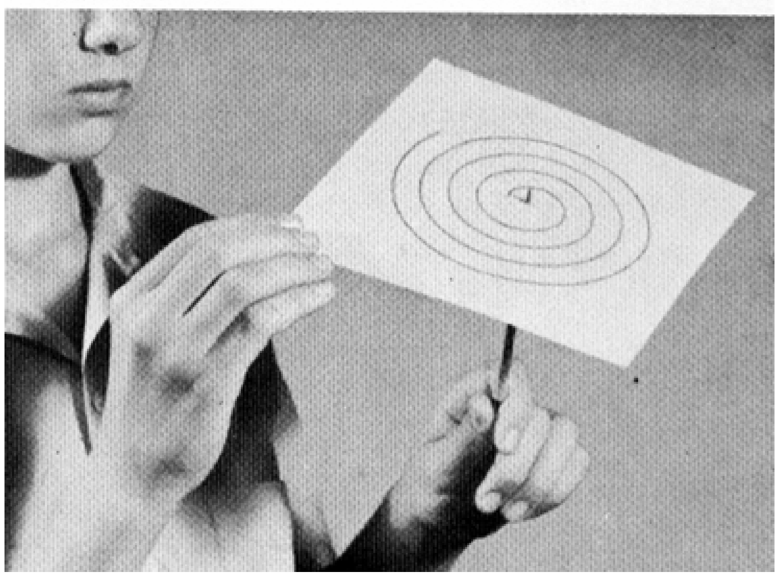
If you want to see the actual path of a thrown body, experiment with a garden hose, as Robert is doing in the picture. Each drop of water coming out of the nozzle acts like a bullet shot from a gun. All of the drops together trace out the parabola.

This interesting curve has many valuable qualities. The huge mirrors used in searchlights and in large telescopes for studying the stars must be given the shape of a parabola. In this way, the light rays coming from a distant star are reflected to form a sharp image. The new Mount Palomar telescope in California has the largest parabolic mirror ever made. It is 200 inches across!

The graceful cables of a suspension bridge are parabolas, too.

SPIRALS



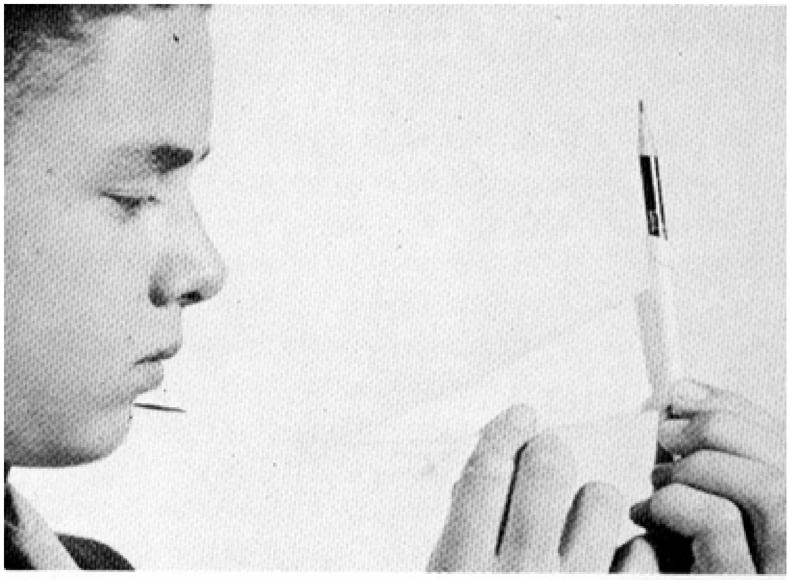


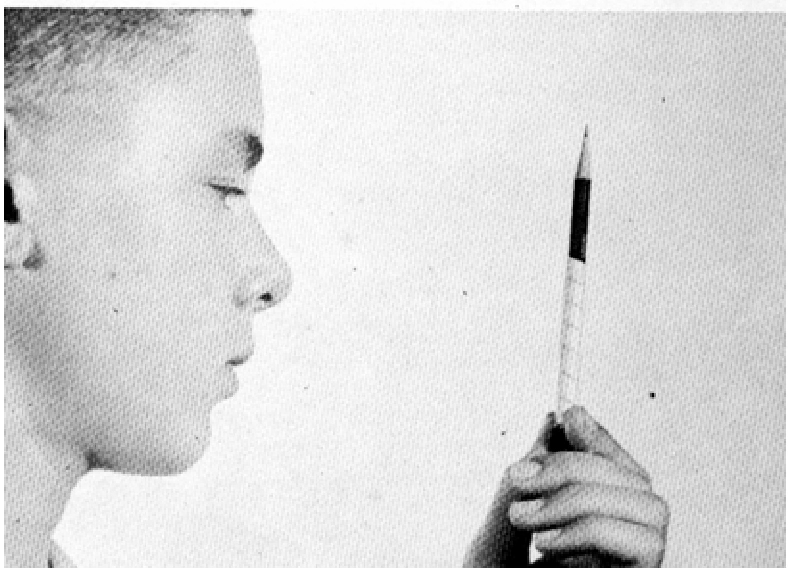
Spirals are familiar curves. The hair-spring that drives the balance wheel of a watch or clock has this form, and so does the shell of a snail. Water running out of a wash basin follows a spiral path.

It is not difficult to draw a good, regular spiral curve; the upper photograph shows how. Place a large square card on a board and hammer in a good-sized nail. Tie one end of a piece of string firmly around the nail and carefully wind on a single layer of string. Make a small loop in the other end of the string. Now put the point of a pencil in this loop and draw the spiral by going around the nail and unwinding the string, pulling it tight all the while.

The lower picture shows the finished curve. Robert has removed the nail and placed the card on the point of a pencil. When he now spins the card, the curve will seem to move outward from the center as it turns in one direction and inward when it turns the other way.

THE HELIX





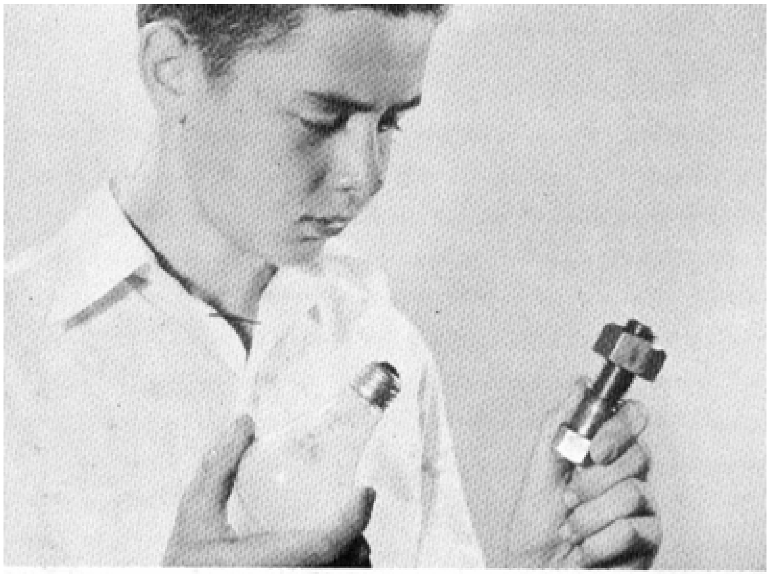
The spiral just described is a curve that lies on a flat surface. There is another curve which looks quite similar because it, too, goes ‘round and ‘round—but it has an added feature. Instead of remaining flat, this new curve rises steadily while going around a center. It is called a <u>helix.</u>

A figure that cannot be drawn on a fiat piece of paper is quite hard to imagine, so make a model of a helix in the following way:

Cut a long, narrow right triangle out of paper, making the short side about 3 inches in length and the long side about 10 inches. Starting with the short side, wrap the paper triangle tightly onto a round stick or pencil, the way Robert is doing in the top picture. When the paper is all wound on, the edge will form a perfect helix such as Robert has in the lower picture.

The stripes on a barber pole or on a stick of old-fashioned peppermint candy have this form. So does a spiral stairway.

THREAD OF A SCREW



The helix does its most important and practical job when used as a screw thread. This form is what makes a screw push forward at an even rate when it is turned. By using only a medium amount of twisting force, a great load can be lifted by means of a jackscrew such as those used in building construction and in tunneling.

In the first picture, Robert is examining the threaded base of an ordinary electric light bulb and the thread of a large bolt. Turning the lamp bulb in its socket moves it inward so that it makes contact and holds firmly.

The propeller of an airplane is really a screw, and in England It is actually called an airscrew. Although an airplane propeller does not really cut its way through the air in the same manner as a screw does through a block of wood, the path of the tip of the propeller traces out a helix as the plane moves along.

QUIVER PICTURES

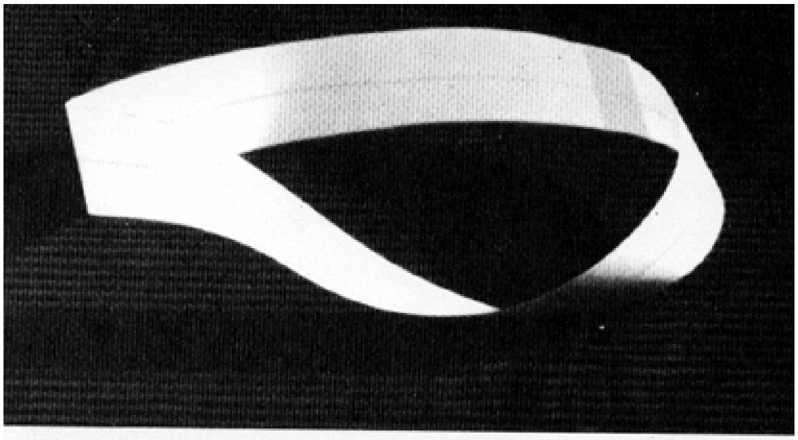
High speed machines often have parts that must move jerkily and this makes them vibrate, or shake quickly back and forth. Such vibrations waste power and make the machine noisy. They also shorten its useful life. An airplane wing, if not designed correctly, will begin to tremble as the plane speeds up, and the quivering may finally become so great that the wing will break off. In order to build machines that are sturdy and safe, engineers must learn as much as possible about vibration. They do this by studying figures traced by the vibrating parts, and this is where geometry is useful.

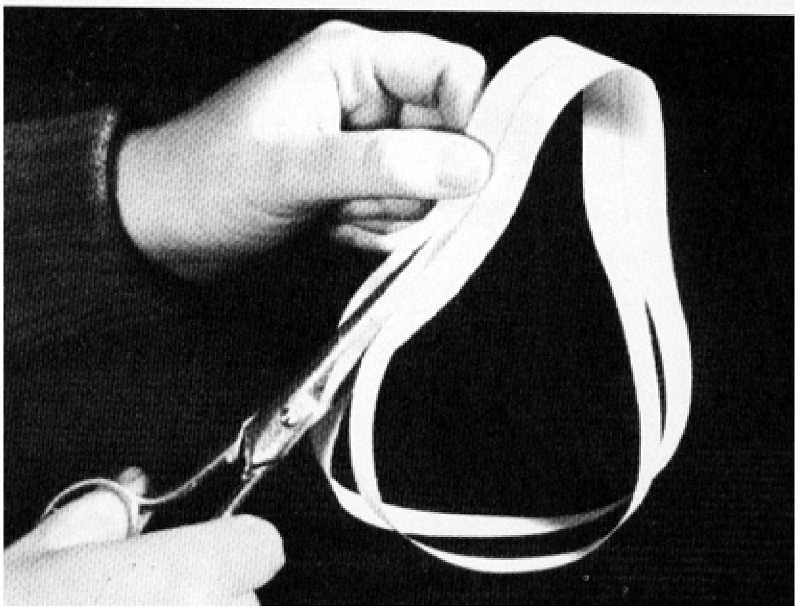
Watching a weight swing on the end of a string is a good way to see vibration in "slow motion." The picture shows you how to make this movement draw its own path, just as the delicate instruments of the engineers do.

To get vibrations like those usually found in machines, the string carrying the weight is hung from a crosswise string. Use a paper cone filled with salt for the swinging weight. Cut off the very tip of the cone to make a small hole that will let a thin stream of salt run out.

Lay a piece of cloth on a board to catch the salt where it falls. Fill the cone, keeping the hole closed with your finger. Then pull the cone aside and toward you and let it go. The salt will stream out, leaving a picture of its path. In order to get different patterns try changing the lengths of the strings.

ONE-SIDED PIECE OF PAPER





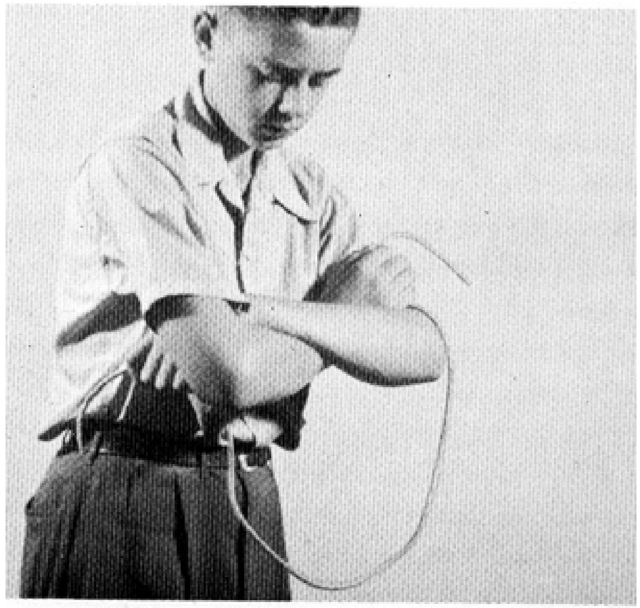
Have you ever seen a piece of paper that has only one side? This may seem to be a trick question because everybody knows that an ordinary sheet of paper has two sides, like the page you are now reading.

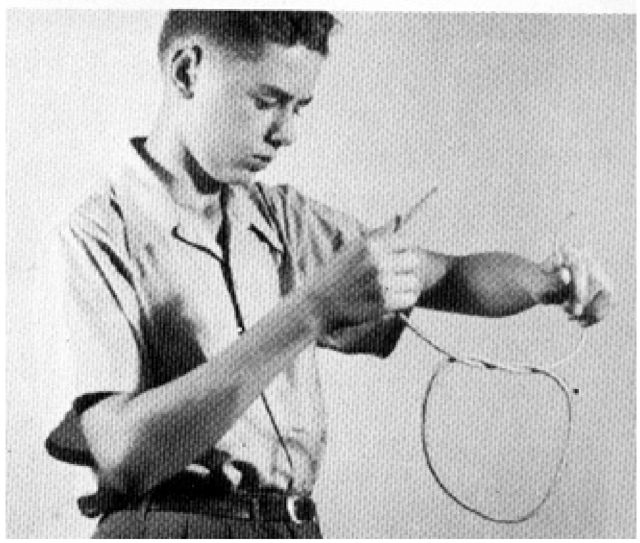
To show that there really is such a thing as a paper with only a single side, make one. Cut a strip about 11/2 inches wide and 18 inches long. If you paste the ends of this strip together, the result is an ordinary round band. Naturally, it has two edges, an upper and a lower one. It also has an inside and an outside, and if you imagine an ant crawling on the outside of the band, it would have to cross over an edge at some point to get to the inside.

Cut another strip of the same size. This time, take an end of the strip in each hand and give one of the ends a half turn before pasting it to the other, so that it looks like the upper picture. Now, starting at any point, you will find that you can draw an unbroken pencil line clear around the paper, returning to the starting point without ever crossing an edge. Try it. It is true, then, that this particular piece of paper has only one side!

But that is not all that can be done with this unusual band. Stick the point of a scissors into the paper and cut all the way around, following the pencil line. The lower photograph shows how to do this. The result is a closed band twice as long and having four twists in it. Finally, cut this narrower band along its center and you now get *two linked* bands.

KNOTS

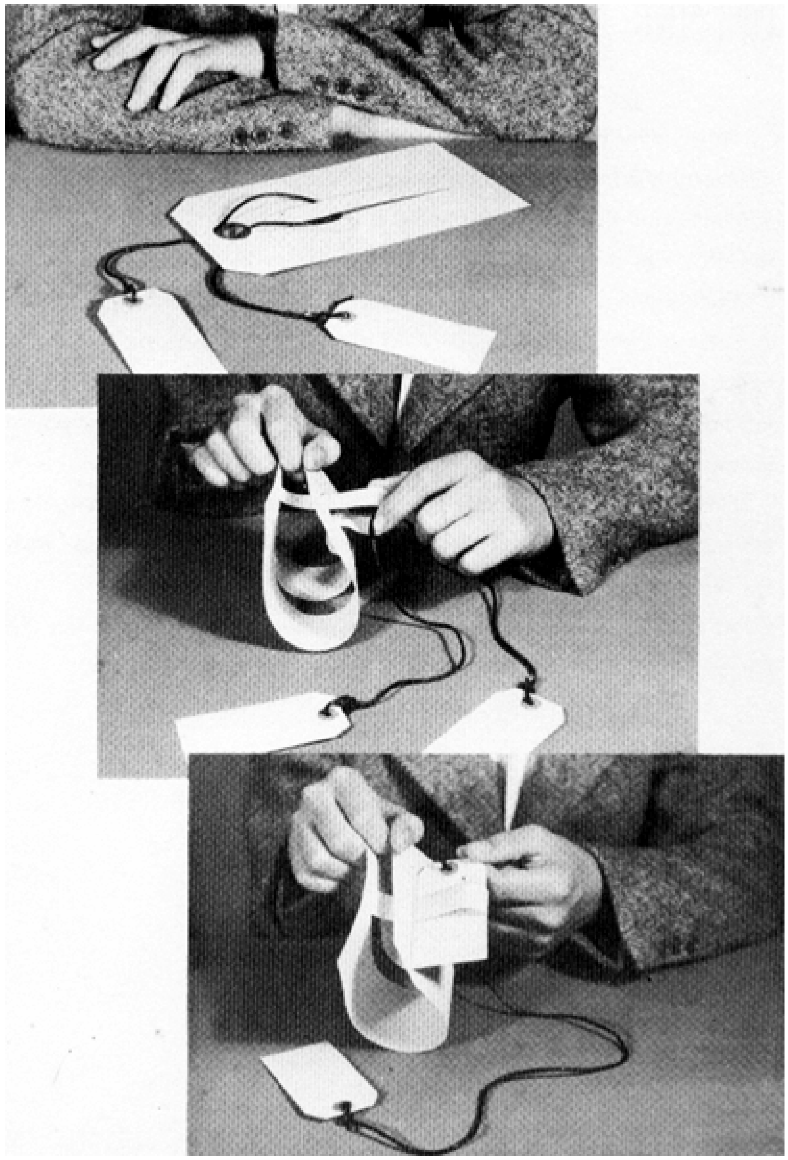




The study of subjects like the one-sided band is a separate branch of higher mathematics that works out how things are connected in space. Tying a knot is just such a question, and is not always as simple a task as it seems. For example, you tie your necktie every morning almost without thinking about it, but did you ever try to tie a necktie on someone else? You would make amusing blunders and would have to stop and think at each step.

Here is a good knot-tying feat. The problem is to tie a knot in a piece of string without letting go of the ends. You know that an ordinary knot is made by looping the string and pulling the free end through. But how can it be done without letting go of this end? Merely lay the cord on a table, fold your arms and then pick up the ends of the cord as Robert has done in the first picture. Now, if you unfold your arms while holding on to the ends of the string, the knot will be complete, as the second picture shows. The idea is that you really tied your arms in a knot when you folded them. Then you simply transferred this knot to the string. But there must always be a knot somewhere to begin with.

THE THREE TAGS

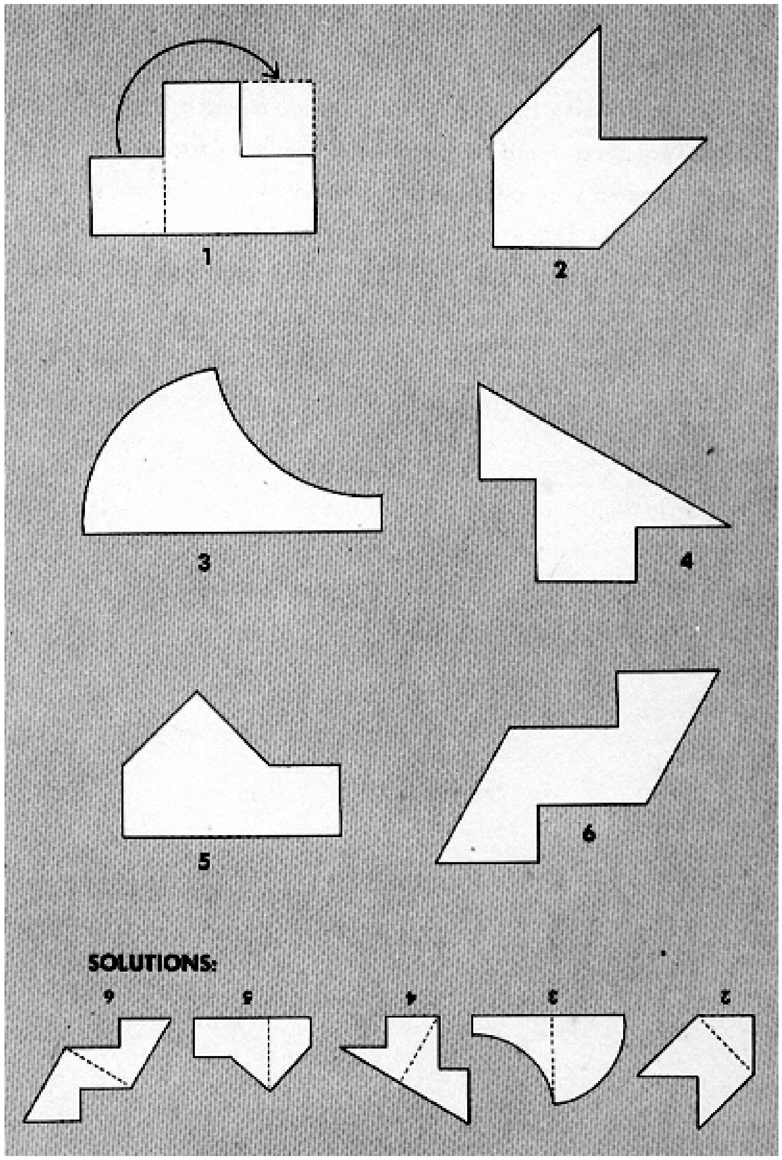


Here is another problem dealing with the way things are joined together. Make up three tags of flexible cardboard and connect the pair of small ones by a string threaded through the large one, as in the top picture. The hole in the big tag should be a little wider than the space between the slits.

Can you see a way to separate the small tags from the large one? Of course the small tags are too wide to pass through the hole. This is how it can be done: Pull the slitted part of the big tag through the hole to form a loop, as in the middle photograph. Then you can easily slip one of the small tags out through the loop and so take the set-up apart.

As in the problem of the one-sided paper band, the stumbling-block here is that we usually think of pieces of paper flat on the table instead of twisted in space.

CUTTING AND FITTING



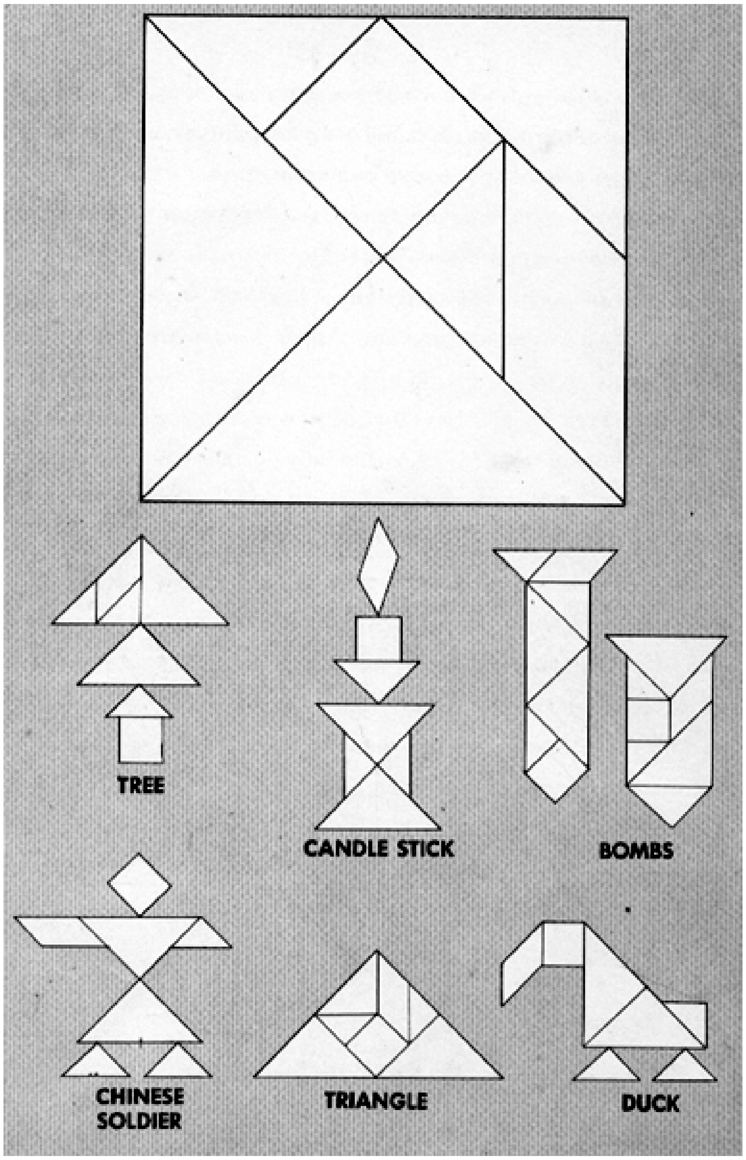
How clever are you at picturing geometric figures in your mind? In geometry it is important to be able to imagine in advance how things will look, and the way to get this skill is to practice. Test yourself with the drawings on the opposite page.

Each figure is to be divided into two parts by one straight cut of a scissors so that the two pieces can be put together again to form an exact square. For example, if Figure 1 is cut along the dotted line, the left-hand piece can be moved over and placed above the other part to form a perfect square.

Find how to divide the remaining figures, not by actually cutting them out but by imagining this done. Of course, if you prefer, you can trace the sketches off on paper, cut them out and work with these.

At the bottom of the page, printed upside down, are the solutions for the remaining figures with the proper cuts shown by dotted lines.

TANGRAM

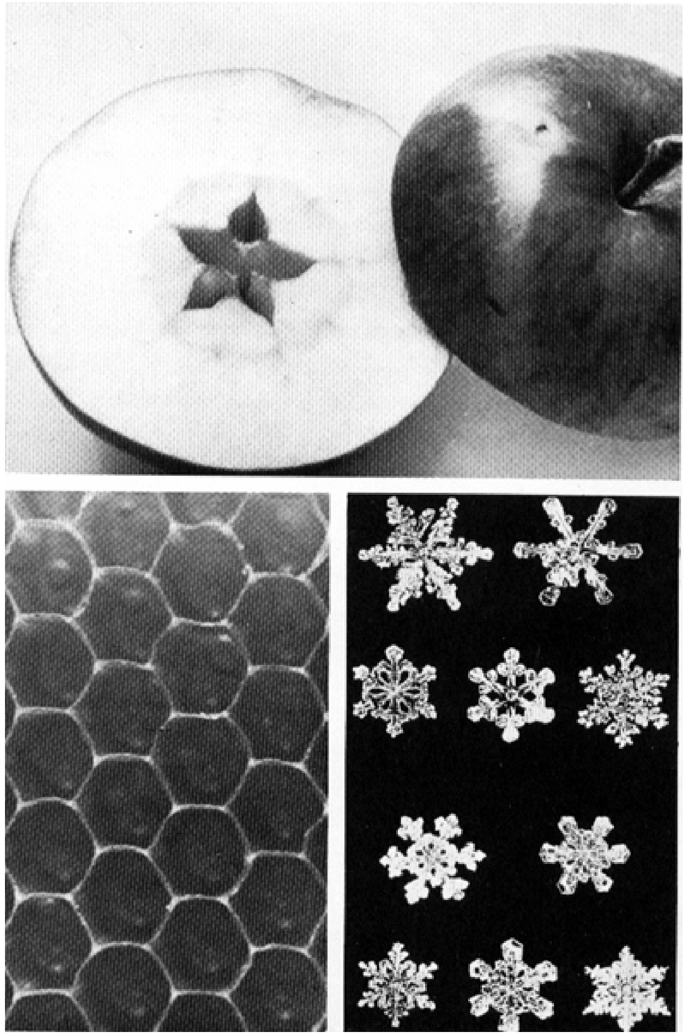


The large drawing shows a Chinese design called a Tangram. Trace it onto stiff cardboard and cut the seven pieces out carefully.

These parts may be put together into an almost endless variety of shapes and figures. This is possible because of the many matching angles and sides to be found on the pieces. Notice, for example, that although the triangles differ in size, they are all of the same shape.

A few of the many possible figures are shown on the opposite page. See how many more you can find by fitting together the seven pieces.

NATURE'S GEOMETRY



Because geometry is a branch of mathematics, it is usually thought of as something worked out by man. But geometric shapes existed in Nature long before there were any human beings on earth.

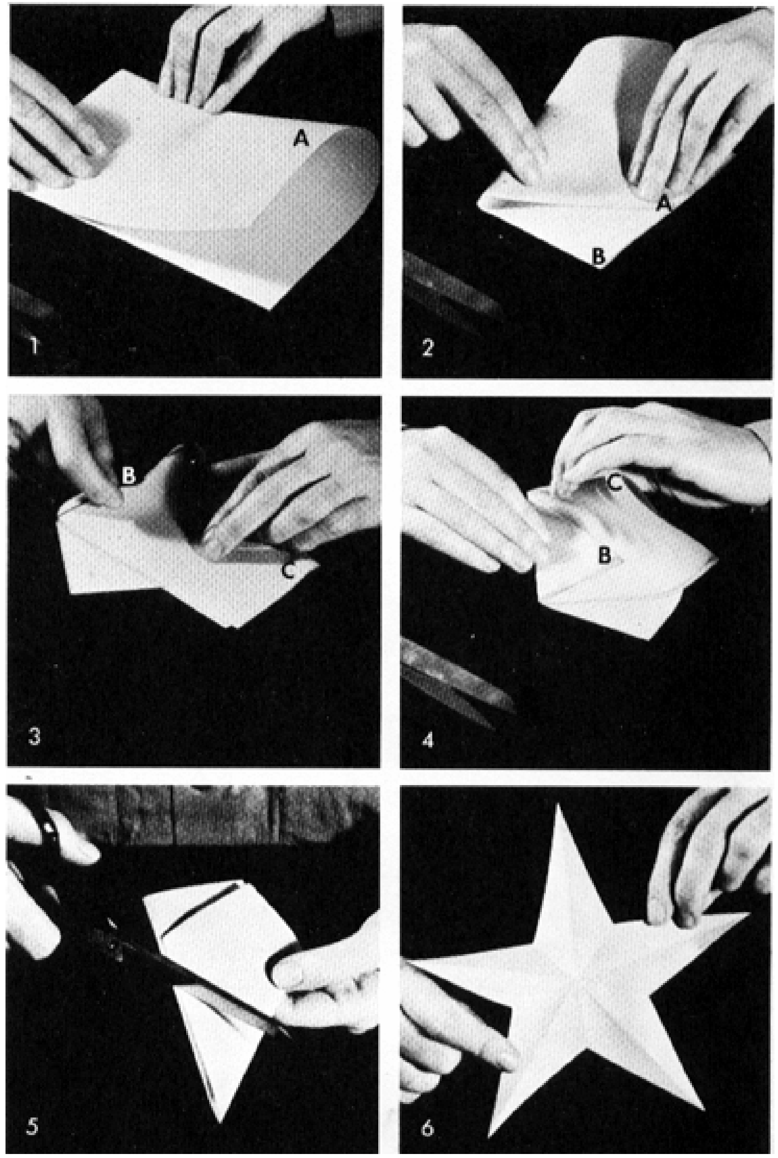
For example, many growing things show geometric balance and evenness in their appearance. The large picture is that of an apple which was cut crosswise. The seed pod forms a very regular five-pointed star. The apple blossom, too, and many other flowers have this five-sided regularity.

Snowflakes are found to have an almost endless assortment of designs — no two of them are exactly alike. But they all have six-sided evenness, and this is because they are made of ice crystals which themselves are six-sided.

Another wonderful example of geometry in Nature is found in the honeycomb. Pictured here is the cross-section of a real honeycomb enlarged about 16 times in area. It shows that each cell is a regular six-sided figure. This is truly remarkable because mathematicians have proved that such a form requires the least amount of wax to hold a certain amount of honey.

You can find many other geometric designs in Nature in the form of minerals, seeds, berries, sea shells, fruits and flowers.

STAR CUT-OUT

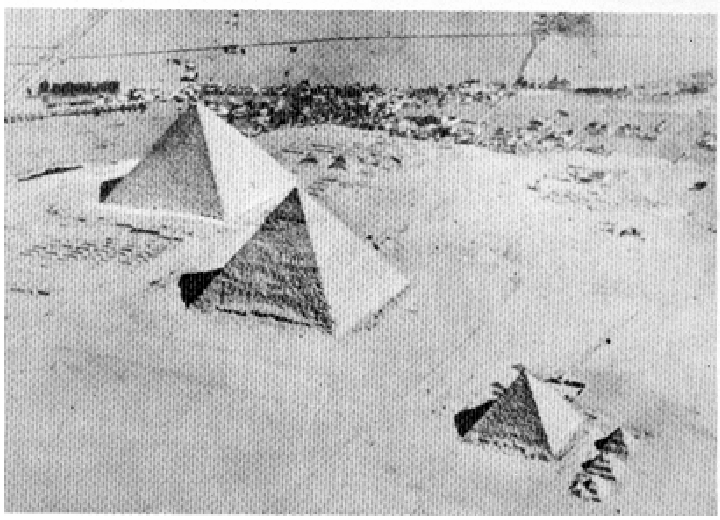


The regular five-pointed star like that on our flag has been a popular ornamental figure for centuries. Old drawings show that such stars were favorites of magicians and astrologers. Today this figure is seen in our Army and Navy rating marks, in the policeman's badge and as a decorative design. Of course there is no direct relation between this geometric shape and the stars in the sky, except that a real star seems to be surrounded by rays of light which suggest the points of the geometric star.

The series of photographs shows how to make a perfect star by folding and cutting a piece of paper. Use a sheet of regular 8.5 by 11-inch letter paper. First fold the long side in half, as in Picture 1. Next place the corner marked A (Picture 2) at the center of the opposite edge, as near as you can judge, and fold the sheet flat. Now fold flap B over, as in Picture 3, and then fold flap C over this one (Figure 4).

With one straight snip of the scissors, cut across the folded figure at an angle as in Picture 5. Open up the cut-off part and you have the finished star shown in Picture 6.

OBJECTS WITH MANY FACES

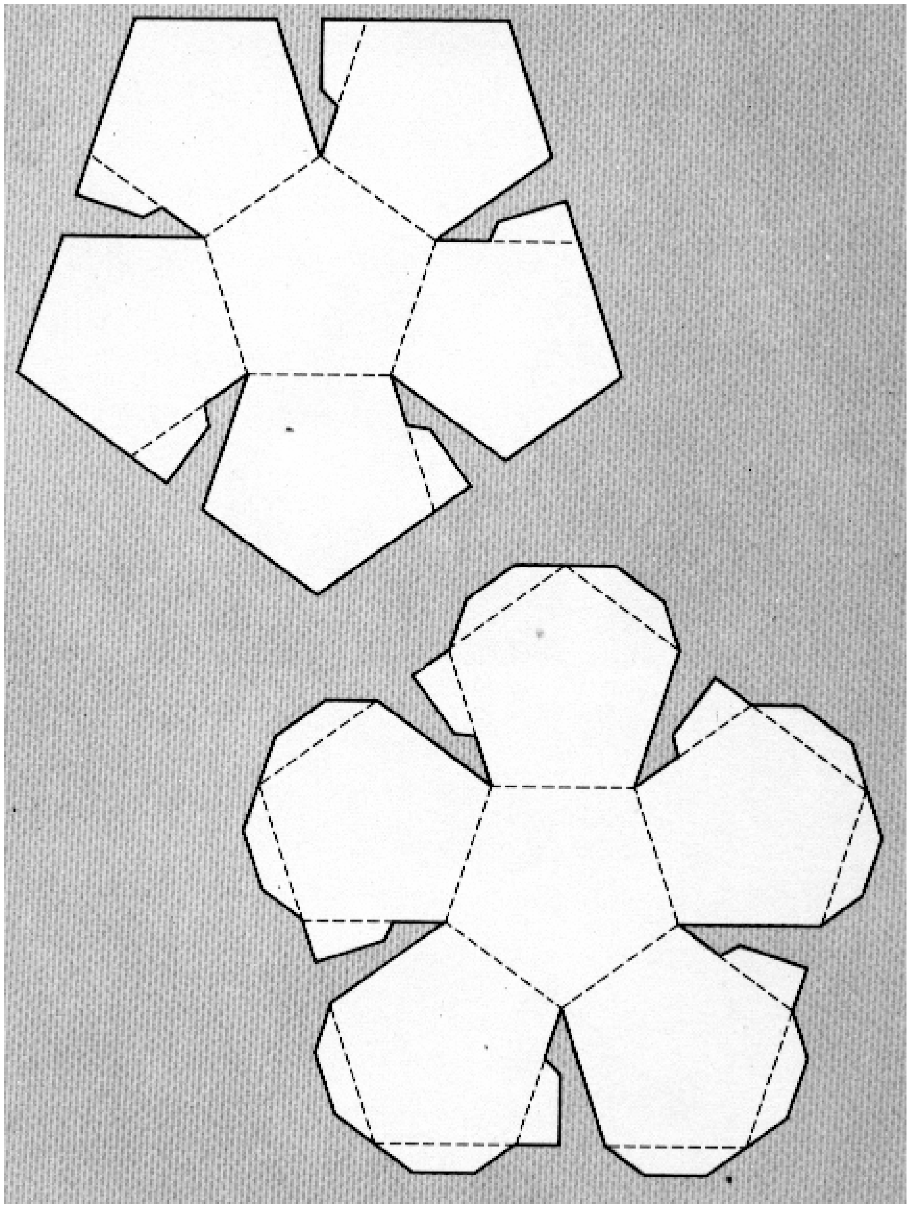


Besides the flat geometric figures that can be drawn on a piece of paper, there are also solid figures that have thickness as well as length and width. A ball, for example, is the solid shape that corresponds to a circle. A football is the solid form of an ellipse. A cube is based on a square.

Among the most ornamental as well as useful solid figures are the ones whose faces are flat and all alike. There are only five possible figures of this kind and you can make paper models of them, like the ones shown in the photograph.

There is the pyramid-shaped solid whose four faces are equilateral triangles. This object looks exactly the same, no matter on which of the faces it rests, and it resembles the famous Pyramids of Egypt pictured below. On the table also is the familiar cube; It has six faces, each being a square. Then there is a less well-known solid figure having eight equilateral triangles as faces. The object at the extreme right is made up of twenty such triangles. Finally, the picture shows Robert putting together the model of a solid with twelve faces, each one having five equal edges.

The models were made by cutting out paper patterns and pasting them together at the edges. On page 60 you will find patterns for the two parts of the twelve-faced object. Trace these very carefully on a separate piece of paper. Then cut along the solid outside line. Next, fold carefully upward along each dotted line, using a ruler. Paste or glue each flap to its neighboring edge, and then join the halves to form the complete solid figure.



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